THURSDAY, DECEMBER 24, 1914.

## ROGER BACON AND GALILEO.

(1) *The Life and Work of Roger Bacon.* An Introduction to the Opus Majus. By J. H. Bridges. Pp. 173. (London: Williams and Norgate, 1914.) Price 3*s.* net.

(2) *Roger Bacon.* Essays contributed by Various Writers on the Occasion of the Commemoration of the Seventh Centenary of his Birth. Collected and edited by A. G. Little. Pp. viii+426. (Oxford: Clarendon Press, 1914.) Price 16*s.* net.

(3) *Dialogues Concerning Two New Sciences.* By Galileo Galilei. Translated from the Italian and Latin into English by Henry Crew and Alfonso De Salvio. Pp. xxi+300. (New York: The Macmillan Co.; London: Macmillan and Co., Ltd., 1914.) Price 8*s.* 6*d.* net.

THE seventh centenary of Roger Bacon's birth has been happily signalised by the republication in a separate handy volume (1) of the admirable "Life and Work" which the late Dr. Bridges prefixed to his edition of the "Opus Majus"; and by the issue from the Clarendon Press of a collection of essays (2) by eminent specialists, British and foreign, dealing with the different aspects of Bacon's work. To this volume the editor, Mr. A. G. Little, contributes an introductory life, valuable both for its own sake and because the author quotes at length a lucid and judicial estimate of Bacon from a lecture by the late Prof. Adamson.

Dr. Bridges's volume is, perhaps, the best estimate in short compass of Bacon's work and significance. The Oxford essayists follow practically the same order of topics, but treat them in greater detail;—Bacon's indebtedness to Robert Grosseteste (Dr. Baur), his relation to thirteenth century philosophy (M. Picavet), to philology (Dr. Hirsch), the Latin Vulgate (Cardinal Gasquet), mathematics (Prof. Eugene Smith), optics (Prof. E. Wiedemann), alchemy (Mr. Pattison Muir), medicine (E. Withington). Dr. Vogl discusses Bacon's curious theory of the transmission of force in the "De Multiplicatione Specierum"; Prof. Duhem shows wit as well as learning in his amusing history of the principle that nature abhors a vacuum; and Colonel Hime deduces from the ninth, tenth, and eleventh chapters of the "Epistola de Secretis Operibus," unintelligible as they stand, the complete Waltham Abbey formulæ for the refinement of saltpetre and manufacture of gunpowder, by methods which must delight the Shakespeare-Baconians or the admirers of Poe's "Gold Bug."

It is easy to exaggerate Bacon's actual achievements. These masterly essays leave the impression that he made few, if any, positive additions to science. "He gives no evidence of his own proficiency in calculation, nor does he show any conception of the nature of algebra." In geometry "he distinguishes between axioms, postulates, and definitions . . . but he makes no attempt to advance the science or to prove a single theorem." One-fifth of the "Opus Majus" is devoted to optics, but apparently he did little more than reproduce the Arabian tradition through Alhazen, with references to the Greek school of Euclid and Ptolemy. Though he quotes from Philo of Byzantium and Hero of Alexandria the classical experiments of the "chantepleure" and the adhesion discs, he argues the question of the vacuum as a pure Aristotelian and accepts without trial the supposed experimental fact that no power on earth would suffice to lift an inverted glass out of a bucket of water without first tilting the edge to admit air. "On aime à faire de Roger Bacon un adepte précoce de la méthode expérimentale; des pages comme celles-ci nous montrent assez qu'il expérimentait seulement en imagination." It does not do to read into his doctrine of the "Multiplication of Species" a forecast of the wave-propagation of light through the æther; or into the famous passage where he seems to anticipate the steam engine, the aeroplane, and the submarine more than a conviction, quite remarkable for his day, that the proper study of nature would work miracles in the service of man.

Bacon's greatness rests on other grounds. A good Catholic, he was yet of the pestilent class of innovators. He attacked authority. His strong character and original mind set about shaking itself free from the "horse-load" of verbal controversies that filled the schools of his day. He was no mathematician and not much of an experimenter; but it is his immortal glory that he was the first to state explicitly the true method of science, the union on equal terms of mathematics and experiment, with deeper insight than his great namesake who, three hundred years later, thought only of experiment and classification, ignoring the use of deduction. He urged the study of languages and philology in order to provide accurate texts of the Bible and Aristotle, denouncing in unmeasured terms the vices and luxury of the clergy, the stupidity of the philosophers content with their barren summaries and versions by those who knew neither the language of their authors nor the subjects they wrote about. He even dared to find many of the Christian virtues among the wise men of Arabia and the East, and valuable stores of knowledge unknown to Aristotle. It was the aim of his life to sweep all this intellectual treasure house into the service of the church.

> "He was aiming at an enlarged and renovated Catholicism," says Dr. Bridges, "which should bind together and incorporate all that was best and noblest in Hebrew, Greek, and Arabic tradition in the fabric of the Christian Church, for the spiritual government of the world. The keystone of the fabric was supplied by the mistress-science, theology, resting on Mosaic and Christian revelation, consolidated by Aristotelian philosophy, and penetrated by the vital and progressive spirit of natural science."

Profs. Crew and de Salvio have done a great service in their admirable translation (3) of Galileo's less-known dialogues, "Concerning Two New Sciences," *i.e.* strength of materials and dynamics. For though it is Galileo's astronomical work, with its dramatic consequences to himself, which sticks in the popular imagination, he stands among the greatest of the pioneers rather by reason of his advances in mechanics. He was the founder of modern physics, the first to put in practice the method urged by Roger Bacon, where mathematics and experiment go hand in hand.

This book should be in the hands of all teachers and, better still, of all students of mechanics. In the cut and dried text-book, the science leaps to birth full-armed in its panoply of dry propositions; but here we see it emerging step by step at the touch of genius from the very problems of practical life from which it took its rise, and the gain in reality is beyond belief. These are real dialogues, between Salviati, who represents Galileo's views, Sagredo, a wit and scholar, and Simplicio, an Aristotelian philosopher. The conversations are natural, discursive, yet closely reasoned. The Aristotelians are given more than fair play, for Galileo puts into Simplicio's mouth better arguments than they had advanced themselves. The inimitable style, with its lucid simplicity, its flashes of humour and sarcasm, gives the same instant impression of modernity that one gets on dipping after a long interval into one of Plato's dialogues. It loses nothing in the translation, where occasional racy Americanisms—"on time," "cuts no figure," "cut loose from"—seem quite in place.

The lapse of three hundred years is vividly realised in passing from Roger Bacon's scholastic Latin to these conversations that might have appeared in a modern review; from the dim, though explicit, formulation of the true method to its full and easy employment. Here is complete mathematical equipment (of the time) and every deductive conclusion is instantly put to the test of experiment. And surely the experiments are among the simplest and most truly elegant of all time. The guess that the speed acquired by bodies falling down inclined planes between two fixed horizontal levels is the same for all slopes and just sufficient to carry them to the original level *up any slope* (for otherwise a body might be made to lift itself unaided above its level) is tested by the most beautiful experiment of all—where the pendulum is set swinging and when the string is intercepted by a nail fixed at any height, the bob is found always to rise to the same level whatever circle it is compelled to pursue. Here, too, is the immediate inference of the First Law of Motion. For if the slope up which the body travels towards its original level is gradually reduced to the horizontal, *it will never get there,* and will therefore go on for ever, being now under the action of no forces!

There follows the famous discussion of falling bodies. The change of the point of view is at once apparent when the fruitless question *why* they fall is set aside until it is found *how* they fall. Simplicio suggests the natural view that the speed acquired is proportional to the distance fallen. But this is shown to be an impossible form of motion, since it implies that it takes as long to fall an inch as a mile. Is it then proportional to the time? In that case it is shown that the distance is proportional to the square of the time; and this is verified by the experiment of the inclined plane and water-clock. One wonders whether most to admire the theoretical insight or the experimental skill. Gravity, therefore, adds equal speeds in every second, however fast the body is moving. This is at once extended to the case of a body projected *across* gravity, horizontally, and the whole theory of the parabolic path of a projectile is deduced. The dialogues are full of interesting digressions, *e.g.* on various orders of infinity (worthy of modern transcendentalists), terminal velocities, brachistochrones, vibrations of stretched strings, the theory of harmony and discord. What a genius!

There are parallels as well as contrasts between these two great men. Both were so convinced of the value of experience that they sought to learn from common people. Thus Bacon, speaking of Peter of Maricourt:—

> "One man I know, and one only, who can be praised for his achievements in this science. . . . He is ashamed that any things should be known to laymen, old women, soldiers, ploughmen, of which he is ignorant. Therefore he has looked closely into the doings of those who work in metals and minerals of all kinds." And again, "They are willing to lower themselves to the level

of husbandmen, of poor women, of children. Many things are known to the simple and unlearned which escape the notice of the wise."

In this spirit Galileo opens his dialogues:—

"The constant activity which you Venetians display in your famous arsenal suggests to the studious mind a large field for investigation, especially that part of the work which involves mechanics; for in this department all types of instruments and machines are constantly being constructed by many artisans, among whom there must be some who, partly by inherited experience and partly by their own observations, have become highly expert and clever in explanation."

Three hundred years again, and Faraday, perhaps Galileo's only superior as an experimenter, writes down:—

"Whilst passing through manufactories . . . we are constantly hearing observations by those who find employment in those places, and are accustomed to a minute observation of what passes before them, which are new or frequently discordant with received opinions. These are generally the result of facts, and though some are founded in error, some on prejudice, yet many are true and of high importance to the practical man. Such as come in my way I shall set down here, without waiting for the principle on which they depend."

This is indeed the scientific spirit, a long, long way from the schoolmen!

Both Bacon and Galileo were good Catholics, and both had sympathisers among the magnates of the Church, including the Popes. Yet both were imprisoned and had their teaching condemned, and both may be said to have forced their own imprisonment. Relying on their protectors in high places they attacked the orthodox teaching of their times, and with characteristic weapons, Bacon with the bludgeon of savage invective, Galileo with the rapier of irony and sarcasm. Yet though suppressed for the moment, their work was not in vain. It was a passage from the "Opus Majus," quoted verbally in Pierre d'Ailly's "Imago Mundi," which Columbus cited as one of his inspirations to the discovery of the New World, and his proposals for the reform of the Calendar bore fruit in the sixteenth century. So, too, when Milton found Galileo practically a prisoner at Arcetri, old, bereaved, grievously ill and blind, it might have seemed that the powers of obscurantism had prevailed. But the very year when he lay broken and dying there was born in Lincolnshire a child, Isaac Newton, who was destined to bring his work to a triumphant conclusion and place him on a pinnacle of glory. You cannot crush the human spirit In these days we may take courage from these two great men, for even though freedom should be trodden under the iron heel of military despotism, which God forfend, it will revive again, and this time it will not wait three hundred vears for its resurrection.

## TOOTH OF MAN AND BEAST

*A Manual of Dental Anatomy, Human and Comparative.* By Dr. C. S. Tomes. Seventh Edition. Edited by Dr. H. W. Marett Tims and Prof. A. Hopewell-Smith. Pp. vi+616. (London: J. and A. Churchill. 1914.) Price 15*s*. net.

IF one imagines, for tableau representation, a quickening of the action in the slow-moving epic of organic evolution, a forward position of immense significance was surely in sight when the scaly armour of certain fishes became so elaborated that they went forth muffled in spines to the very lips. And the defence and protection was completed—and something more than these was initiated—when the dermal spines were drawn over the lips and carried into the mouth itself, there to form the beginnings of those wonderfully diversified structures which are known as teeth. Many eminent workers have, along various byways of inquiry, been attracted to, and held by, the study of odontology, and have helped to build up a most noticeable body of scientific knowledge. Tomes's "Dental Anatomy" still holds the field as, perhaps, the most successful effort to gather and arrange the facts, and present them in a "manual" suitable for students and beginners. The author and his editors are to be congratulated upon the production of the seventh edition, in which the make-up is improved by a larger page and type, and by bringing the matter descriptive of illustrations directly under each figure, instead of at the foot of the page.

The desire of the editors "to incorporate in the volume the results of recent research" has not brought about the addition of much new matter. But the ordinary student is not likely to be found grumbling before such a well-spread table; the number of published "note-books" and compilations of the "cram" order that have sprung from the parent work of Tomes shows that he suffers gladly any reduction of bulky fare. The acute controversies that turn upon such problems as enamel formation, dentine innervation, and the homologies of teeth, remain apparently unsettled, and in regard to these and many other disputed points there may be some disappointment that, after the lapse of a decade, the very wide catholicity of Mr. Tomes's interesting discussions